Sabertooth: Integrated Avionics for Small Spacecraft Missions

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William Whitaker
Advanced Computer Systems and Technologies Group, JPL

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Jet Propulsion Laboratory
California Institute of Technology

Advanced Computer Systems and Technologies Group

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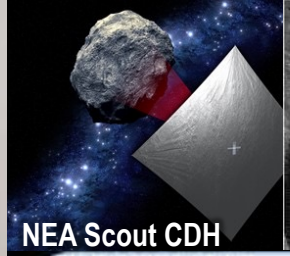
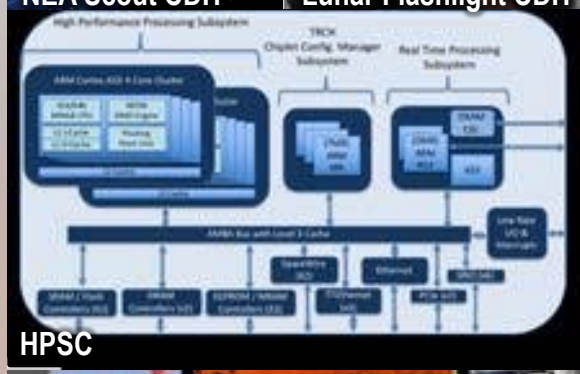
Avionics development for Sabertooth is being led out of the Advanced Computer Systems and Technologies Group at the *Jet Propulsion laboratory*, which develops computing and avionics platforms for future spacecraft and specialized missions.


49-Core Computer for Autonomous Landing


NEA Scout CDH


Lunar Flashlight CDH



HPSC


Heterogeneous Processing for Fast Mobility


Mars Helicopter Avionics


Sabertooth integrated Processor and Avionics

Sabertooth Integrated Avionics

Introduction

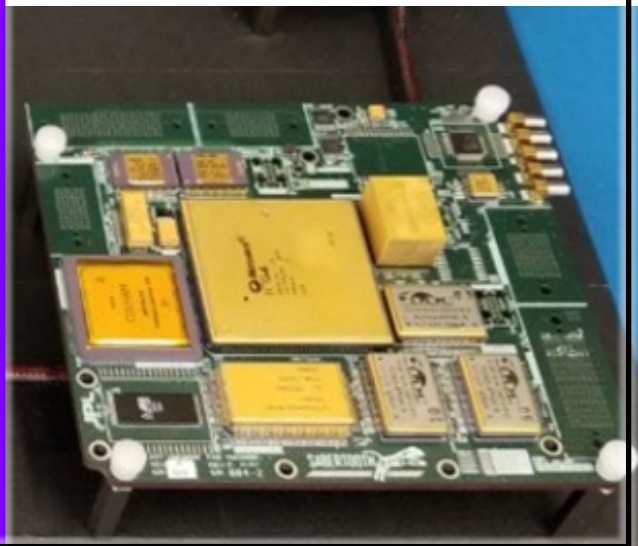
Sabertooth is a integrated high-reliability deep space avionics platform

- Designed to support a variety of deep-space missions
- Combines key avionics functions onto a single slice
- Aggressive improvement Size, Weight, Power, and Cost (SWaP-C)
- Exclusively high-rel parts
- Natively configurable from flight processor to single and dual-string avionics
  - Modular solution which scales to mission needs

Single Board Computer

Single-String Avionics

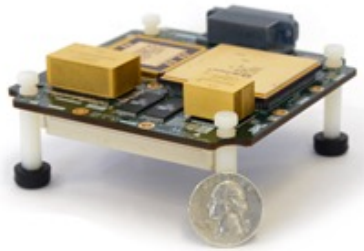
Dual-String Avionics



Sabertooth Integrated Avionics

background and Goals

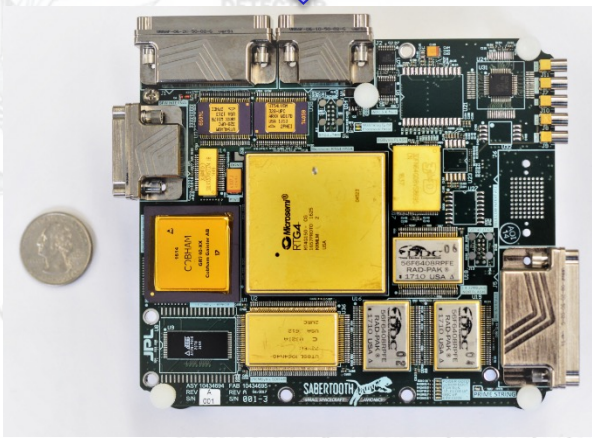
Sabertooth is the follow-on to the Sphinx deep-space cubesat single-board C&DH



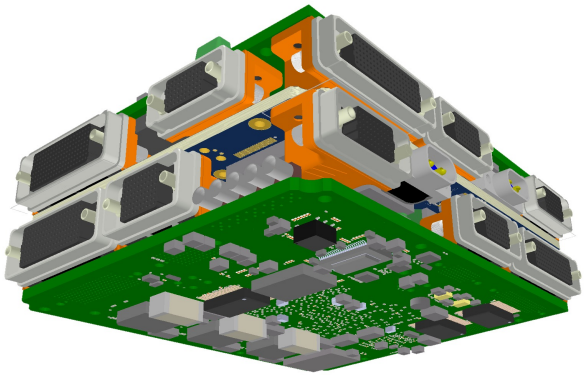
2014
Sphinx

Goals:

- 8-10x improvement in SWaP-C over state of practice Avionics
  - Reduction in Size, Weight, Power, Cost
  - Increase in performance
- Integrate subsystems
  - Eliminate subsystem cabling
  - Reduce Warm Electronics Box volume
- Flagship-class capability and reliability



2017
Sabertooth



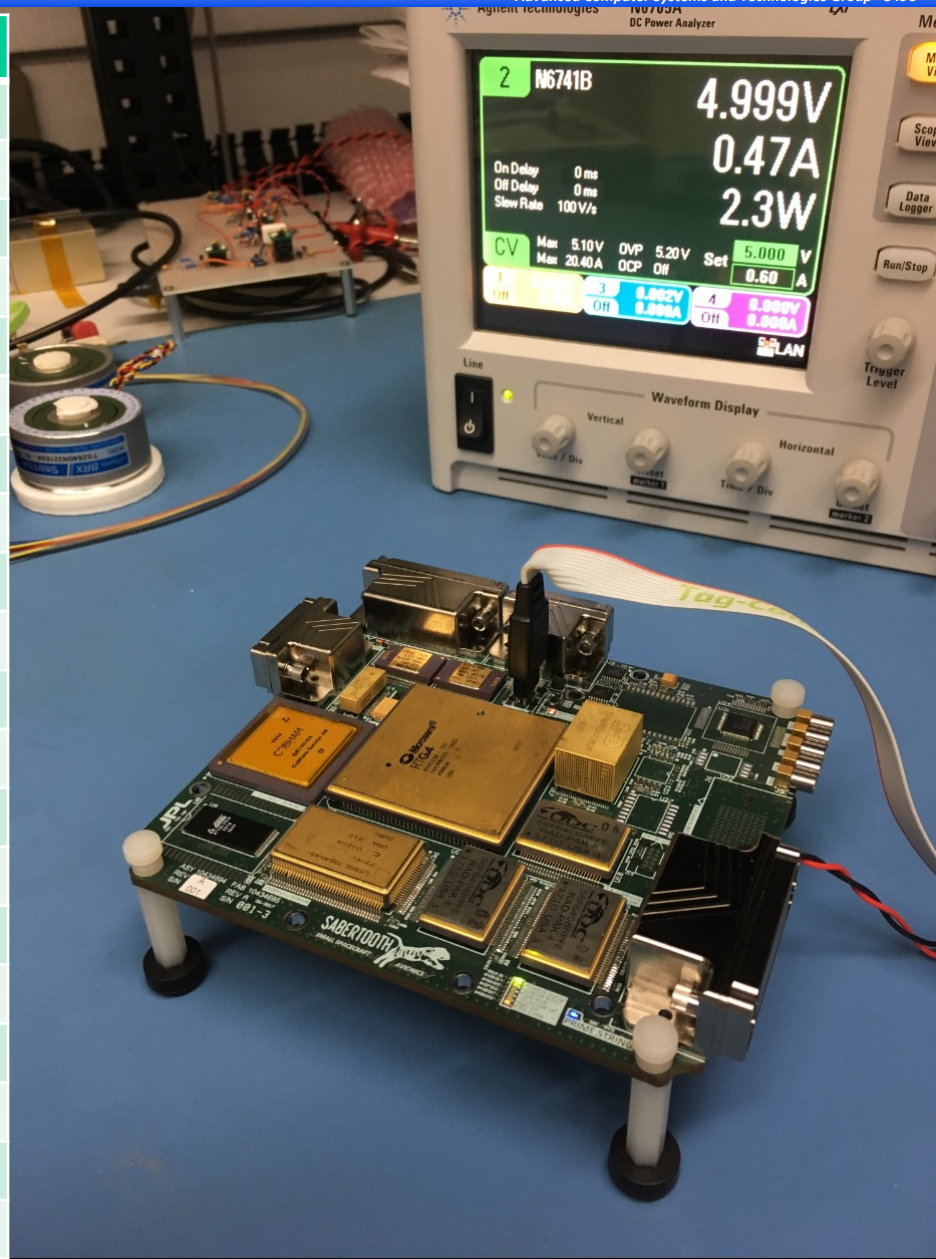
2 Sabertooth Processors + Fault Management Unit Stack-up

Attribute	Class B Sphinx	Sabertooth	State of Practice
Cores:	Dual Core	Quad Core	Single
CPU Performance:	160 MIPS	~1200 MIPS	266 MIPS
Power:	1-3W	currently 4.8W	10+W
Mass:	0.55kg	currently ~3kg	10+kg
Size:	10cm x 10cm x 1.5cm	11cm x 12cm x 4.5cm	cPCI-based subsystems
Radiation (CPU):	300krad	300krad	1Mrad

Sabertooth Integrated Avionics

Key Specifications

Feature	Target
Processor	**GR740 SPARC V8 Processor**
Processor performance	**1200MIPS**
Processor cores	Quad-Core
Power	**3W**
Mass	3kg
Size	**11cm x 12cm**
Radiation (total)	100krad
Radiation (CPU)	**300krad**
FPGA Device	Microsemi RTG4 FPGA
Board Supply Voltage	5V
Data Storage	**8 GBytes NAND FLASH**
Flight Software Storage	**6 X 32MBytes**
Start-up ROM Size	4 x 64kBytes with EDAC
RAM	256MBytes PC100 SDRAM with EDAC
SpaceWire	**8 Channels**
Motor Control	64 channels
GNC	7 channels
Time distribution	64 channels
Telecom	Full Iris transceiver signal processor + DAC/ADC
Packaging	Slice-based, Serial interconnect



Sabertooth Integrated Avionics

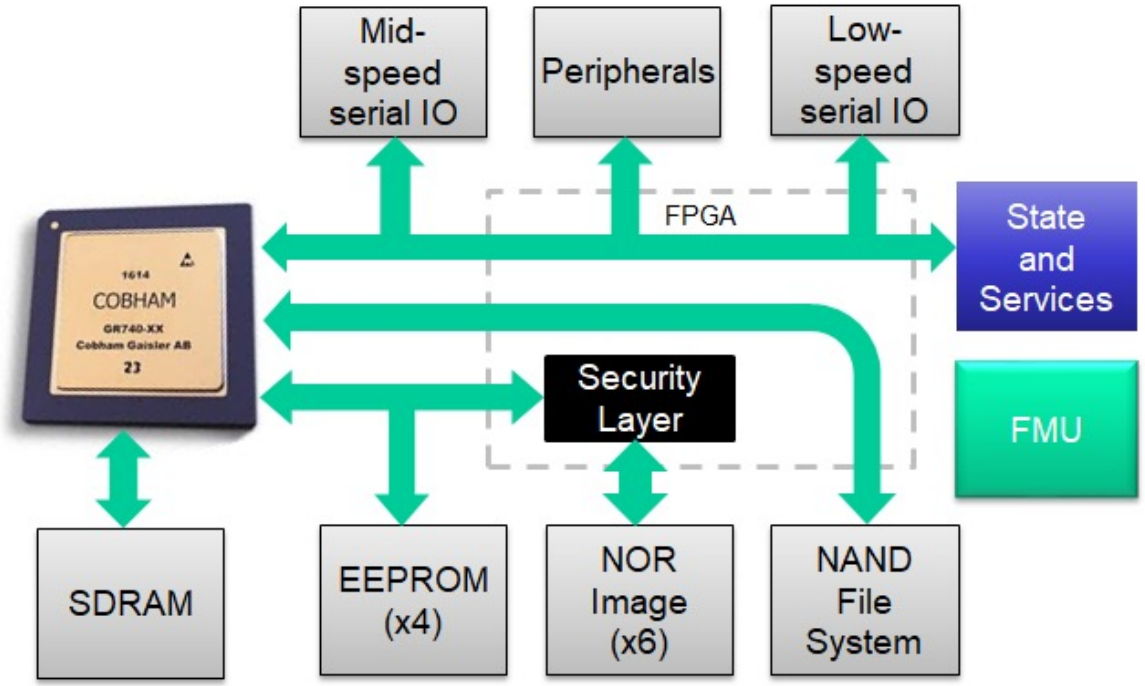
Integration of Key Avionics Subsystems

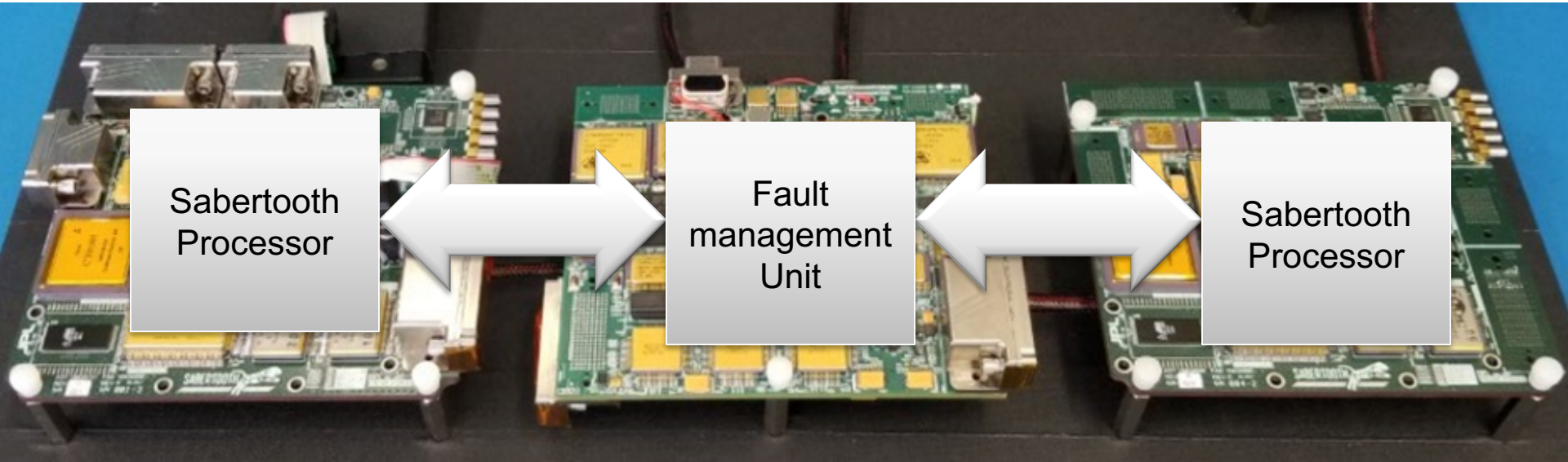
Sabertooth Avionics integrates multiple subsystems into a compact assembly

- Combine traditionally individual subsystems
  - CDH, telecom, Motor Control, GNC, power regulation/switch/housekeeping
- Integrate the functions of consistently-required support cards

Sabertooth Compute layer

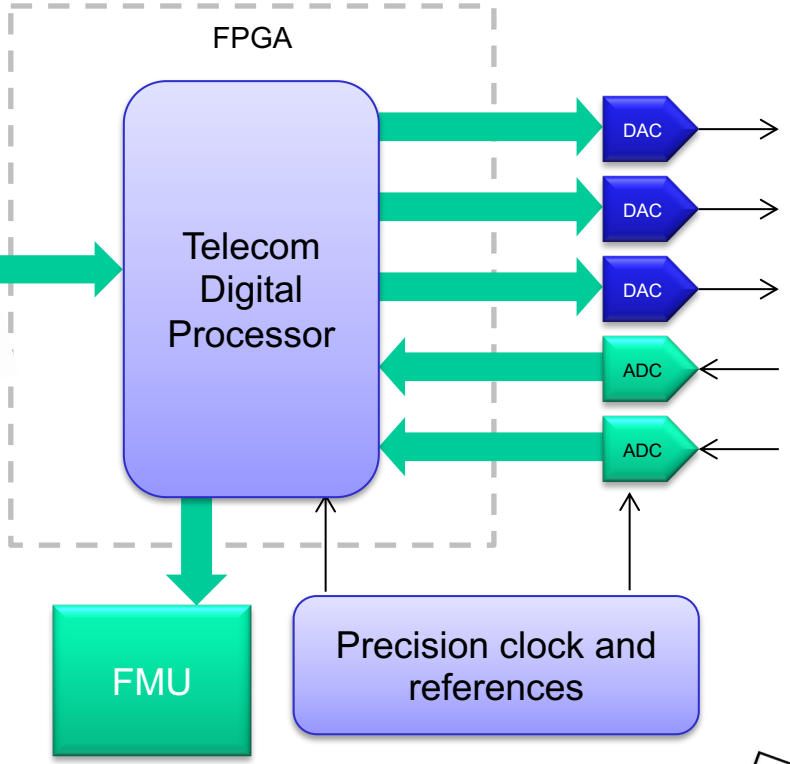
- GR740 Processor
- Spacewire for payload and interconnect
- Low-speed serial
  - SPI / UART / LVDS
- EEPROM bootloader
- FSW image memory
  - Cybersecurity protected
- NAND-based file system

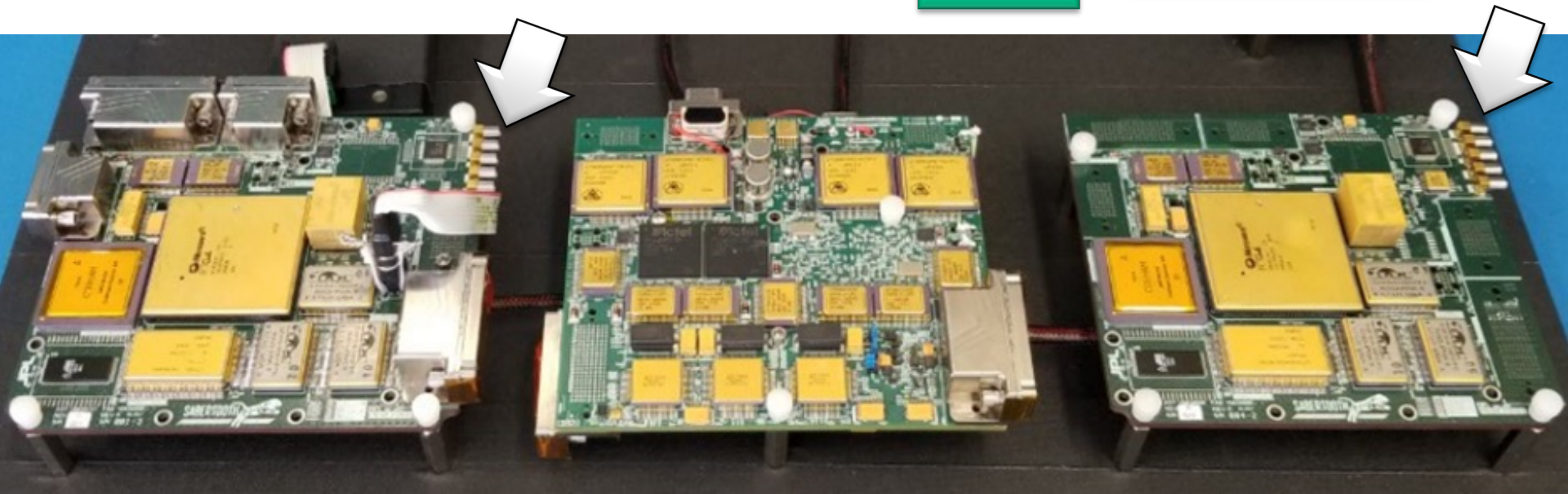




Sabertooth Telecom Layer

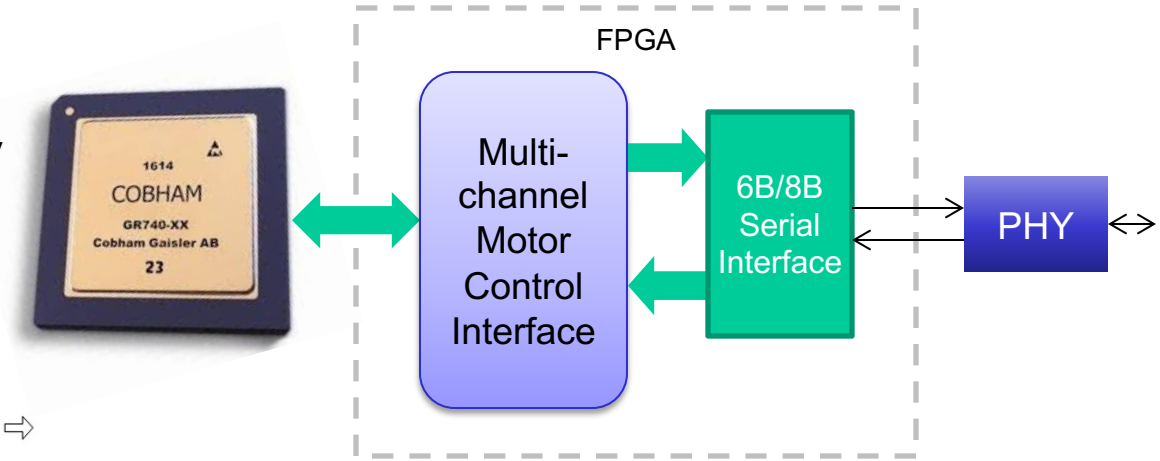
- Integrated Iris deep-space radio
  - Signal Processing
  - ADC/DACs
  - EMI doghouse in frame
- Radio FSW runs on GR740
  - Radio-CDH interface is thread-to-thread
- Radio firecode interface to FMU
- Supports UHF/X/S/Ka-band RF slice

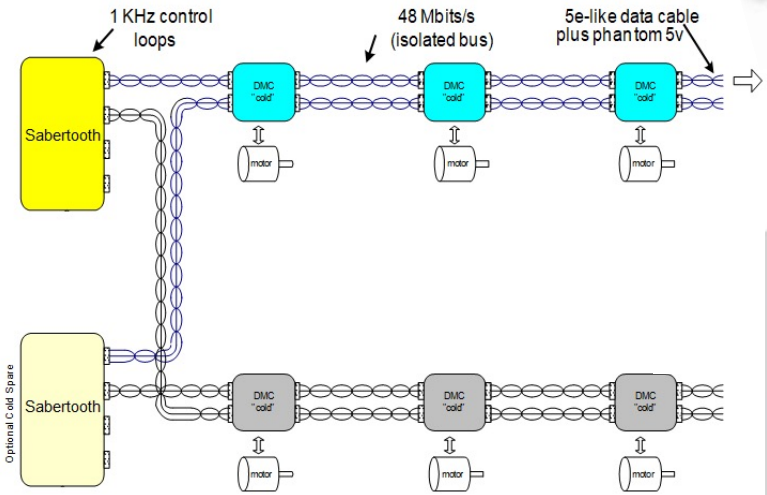


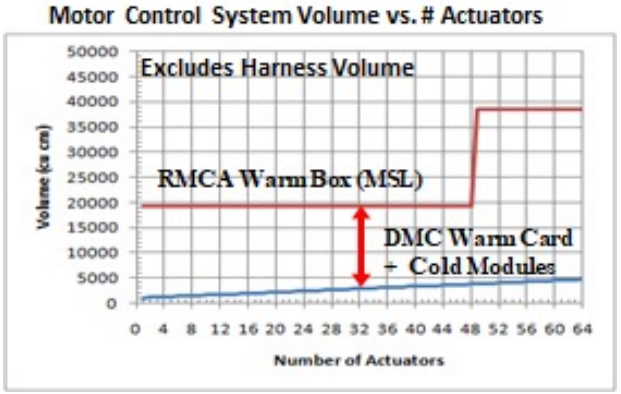


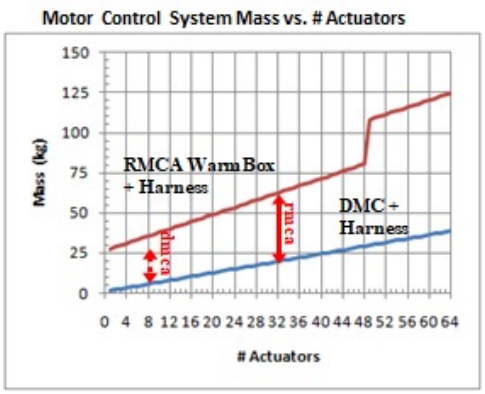
Sabertooth Motor Control Layer

- Distributed Motor Control Architecture
- Design inheritance from M2020 and Mars Helicopter
- All motors connect via a single CAT5 cable
- Improvement in performance while reducing overhead
  - Reduce SWaP
  - Reduce Cable complexity
- HW and SW loop control



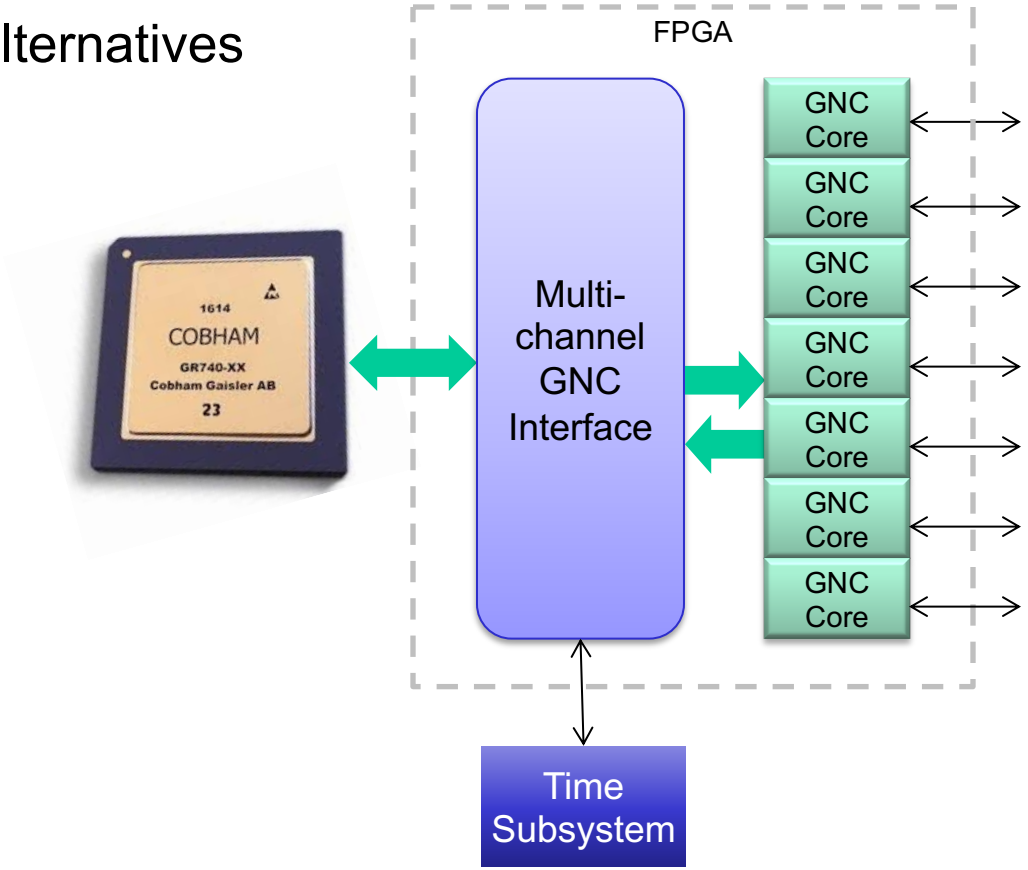






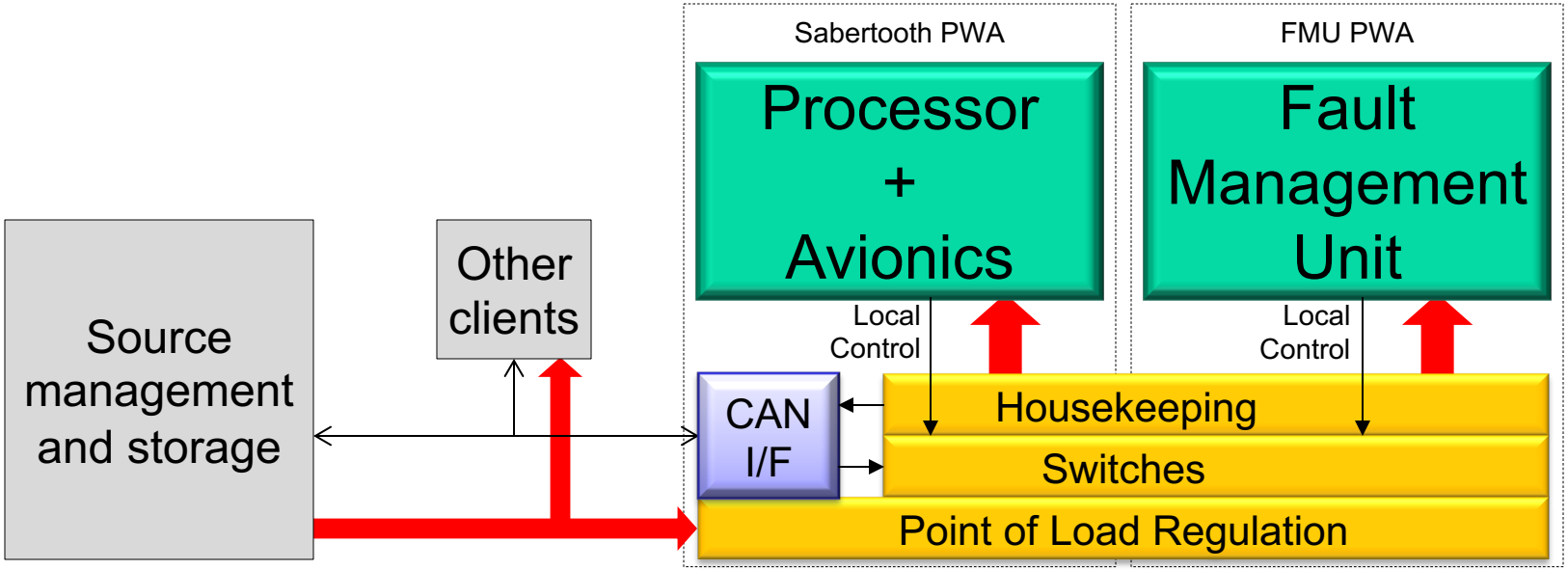
Sabertooth GNC Layer

- Integrated programmable GNC interfaces
  - Programmable GNC devices
  - Provides interface, data strobes/enables/valids
  - Integrated timestamping
- Increase variety and combinations of GNC devices
- No native 1553 support, use alternatives
  - Spacewire,
  - LVDS / 422



Sabertooth Power Layer

- Sabertooth supports a distributed power architecture (DPA)
  - Control and housekeeping via CAN Bus
- DPA is a key element in the significant reduction in power
  - Increased efficiency from source to load
  - Enable fine-grain power management
  - GaN devices
  - Complemented with the low-power-focused architecture and Sabertooth design
  - Supported by efficient flight parts at the load



Sabertooth Integrated Avionics
Challenges

Integrating historically separate subsystems:

Order of magnitude improvement in SWaP requires attention from the system-level down to the components

- Focusing multi-disciplinary team to develop an integrated assembly
- Impact on the whole as important as the optimization of a subsystem
- Adapting to the blurring of subsystem boundaries
- Maintaining reliability while altering traditional fault containment regions

Maintaining a low-SWaP focus:

There is a huge desire for unbounded increases in features which must be managed

- Features are always traded against SWaP impact
- Prioritizing mission-enabling capability
- Containing feature creep with the 80% rule:
  - "support of 100% of the requirements for 80% of the application in the target space"
  - Don't allow the outliers to drive up the SWaP-C for the majority customer

Sabertooth Integrated Avionics
Challenges

Flight Component Limitations:

Sabertooth is a significant increase in function density and modern flight parts are very enabling…

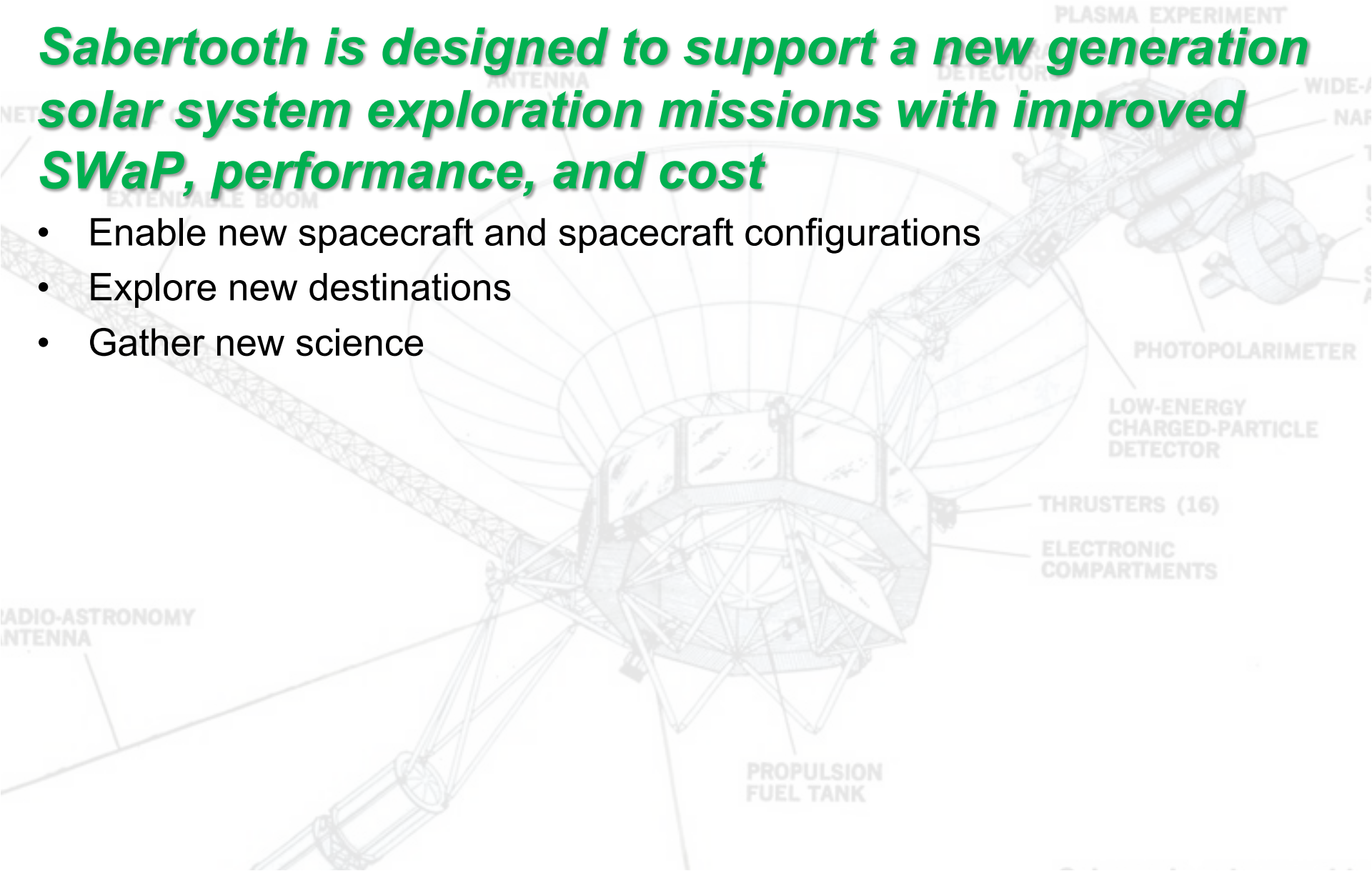
…but flight parts lag behind in some critical areas

- Need reliable rugged high-density connectors
- Need a better selection of instrumentation amps, sense amps, op amps, flight passives (02-01s)
- Flight memories are always a need: high-rel, long life, high density, and low power

Sabertooth Integrated Avionics
Summary

Sabertooth is designed to support a new generation solar system exploration missions with improved SWaP, performance, and cost

- Enable new spacecraft and spacecraft configurations
- Explore new destinations
- Gather new science



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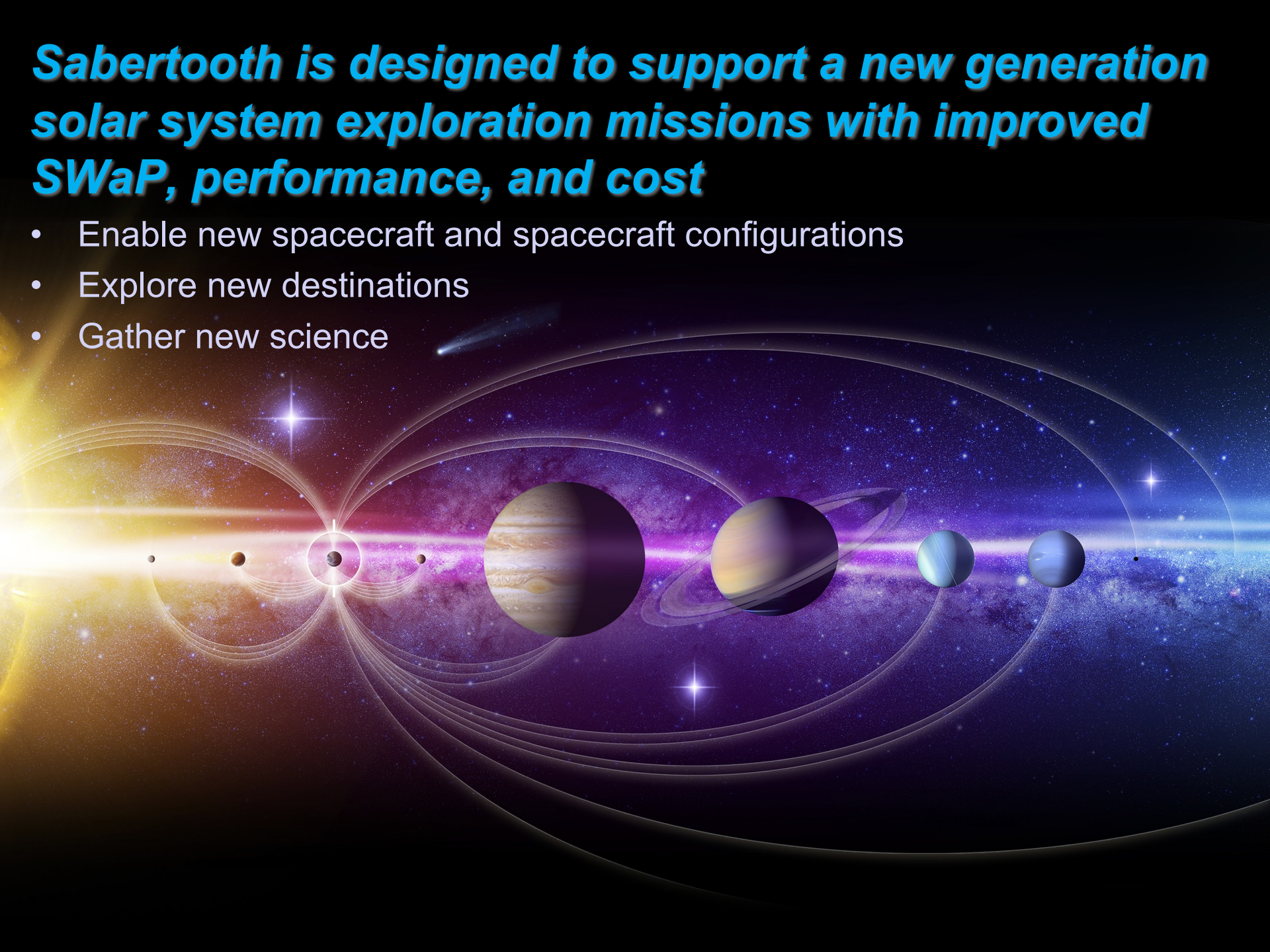


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